

Environmental influences on Elite Sport Athletes Well Being: From Gold, Silver and Bronze to Blue Green and Gold

Aoife A. Donnelly^{1*}, Tadhg E. MacIntyre², Giles Warrington², Nollaig O'Sullivan², Drew Harrison², Brett R. Gordon², Eric R. Igou³, Marc Jones⁴, Chris Gidlow⁴, Andrew M. Lane⁵, Ross Cloak⁵, Ian Lahart⁵, Noel Brick⁶

¹School of Food Science and Environmental Health, Dublin Institute of Technology, Ireland, ²PESS, University of Limerick, Ireland, ³Dept. of Psychology, University of Limerick, Ireland, ⁴Faculty of Health Sciences Staffordshire University, Staffordshire University, United Kingdom, ⁵Research Centre for Sport, Exercise and Performance (RCSEP), Wolverhampton University, United Kingdom, ⁶Dept. of Psychology, Ulster University, United Kingdom

Submitted to Journal:

Frontiers in Psychology

Specialty Section:

Movement Science and Sport Psychology

Article type:

Perspective Article

Manuscript ID:

208067

Received on:

02 May 2016

Frontiers website link:

www.frontiersin.org

Conflict of interest statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest

Author contribution statement

TBC

Keywords

Well being, Olympic Games, Mental Health, elite athletes, Air Pollution, Environmental Health, physical activity

Abstract

Word count: 137

Specifically, we will focus on the concept of 'green exercise' and its impact on mental health and well-being. We suggest that the positive impact of the physical environment has been underestimated, and instead research interests have typically been concerned with ameliorating physiological health risks to athletes. It may be worthwhile to explore the positive impact of the environment in this setting given the abundance of stressors and challenges to athletes' mental health in the elite sport context that are the subject of this research topic. We propose that research must tackle the topic of environmental quality when assessing the psychological benefits of green space on elite athlete health, well-being and performance. Future research will take a transdisciplinary approach to allow us to understand the implicit health effects of green and blue exercise in a range of environments.

Funding statement

This submission was funded in part by an Irish Research Council New Foundations Awards in 2015 to the project entitled: GO GREEN EX: Going Outdoors: Gathering Research Evidence on ENvironment and Exercise in collaboration with Mental Health Ireland. Open access cost are funded by a PESS research start-up award to the second author.

Ethics statement

(Authors are required to state the ethical considerations of their study in the manuscript including for cases where the study was exempt from ethical approval procedures.)

Did the study presented in the manuscript involve human or animal subjects: No

Environmental influences on Elite Sport Athletes Well Being: From Gold, Silver and Bronze to Blue Green and Gold

*Aoife Donnelly¹, Tadhg MacIntyre², Nollaig O'Sullivan³, Giles Warrington³, Andrew Harrison³, Eric R. Igou⁴, Marc Jones⁵, Chris Gidlow⁵, Noel Brick⁶, Andrew M. Lane⁷, Ian Lahart⁷, Ross Cloak⁷, and Brett Gordon³.

¹Dept. of Food Science and Environmental Health, Dublin Institute of Technology; ²Health Research Institute, University of Limerick; ³Dept. of Physical Education and Sport Sciences, University of Limerick; ⁴Dept. of Psychology, University of Limerick; ⁵Centre for Sport, Health and Exercise Research, Staffordshire University; ⁶School of Psychology, Ulster University; ⁷Institute of Sport, Faculty of Exercise, Health & Wellbeing, University of Wolverhampton .

*Corresponding author address: Dept. of Food Science and Environmental Health, Dublin Institute of Technology, Cathal Brugha Street, Dublin 1, Ireland.

In review

Abstract

Specifically, we will focus on the concept of ‘green exercise’ and its impact on mental health and well-being. We suggest that the positive impact of the physical environment has been underestimated, and instead research interests have typically been concerned with ameliorating physiological health risks to athletes. It may be worthwhile to explore the positive impact of the environment in this setting given the abundance of stressors and challenges to athletes’ mental health in the elite sport context that are the subject of this research topic. We propose that research must tackle the topic of environmental quality when assessing the psychological benefits of green space on elite athlete health, well-being and performance. Future research will take a transdisciplinary approach to allow us to understand the implicit health effects of green and blue exercise in a range of environments.

In review

Environmental influences on Elite Sport Athletes Well Being: From Gold, Silver and Bronze to Blue Green and Gold

Introduction

There are currently less than 100 days to the XXXI Olympiad at Rio de Janeiro, where over 10,500 athletes will compete in 42 different sports. This perspective article addresses some of the environmental challenges for athletes. We propose several potential avenues for future research on the salutogenic impact of the natural environment, an aspect that has been largely overlooked in the research literature.

The quadrennial competitive event has been readily accepted as an acute stressor for athletes. This comprises both competitive stressors (Schinke et al., 2012) and organizational stressors (Fletcher et al., 2012). Early research by Greenleaf et al. (2001) who interviewed US Olympians reported departing from normal routine, coach issues and injury were among the major factors that were perceived to have negatively influenced performance. Among the positive performance factors were Olympic housing, and team unity. Athletes have been recommended to “fine tune their mental preparation to suit the special demands of the Games environment to minimize the stressors” (Hodge, 2010, p. 411). More recently, constructs such as resilience and adaptation have been explored to elucidate how athletes thrive with the competitive pressure (Fletcher and Sarkar, 2012; Schinke et al., 2012). While many variables beyond the individual athlete have been explored, including optimizing the role of sport psychologists consulting at the Olympic Games (Sarkar and Arnold, 2014), it is worth noting that the wider ‘natural environment’ in which sport occurs has not been subject to the same level of scientific scrutiny. The effects of environmental pollution must now be considered a global concern among the scientific community for its impacts on human health, the environment and climate change. This research will reveal how environmental quality can not only potentially positively affect physiological health but also mental health and well-being in the elite athlete population. For instance, green exercise, the synergistic benefit in adopting physical activities whilst at the same time being directly exposed to nature (Pretty et al., 2003), is worthy of further exploration. We propose a model where physical and psychological well-being (and better performance) are linked to green and blue environments and suggest that current developments in the Olympic context are in sharp contrast with this model.

The Greenness of Rio de Janeiro

The sport venues for Rio 2016 Olympics have been subject to scrutiny because of the risks to competitors from environmental hazards. For instance, the degraded water quality of 384 km² Guanabara Bay (e.g., Olympic Sailing venue) has been attributed to anthropogenic impacts which have led to heavy eutrophication and the emergence of pathogenic microorganisms (Fistoral et al., 2015). Goals for the restoration of the bay that coincided with the Games (e.g., Rio 2016 Sustainability Plan) may not be met in advance of the September 2016 deadline. Tackling pollution here is not “only of ecological, social-cultural and aesthetic relevance, but is also a public health issue” (Fistoral et al., 2015, p. 14).

Air pollution is a societal concern and is interlinked with other environmental, social and political and economic systems and is the primary environmental cause of premature death in the EU (European Commission 2013). The most problematic pollutants have consistently been oxides of nitrogen (e.g. nitrogen dioxide; NO₂), particulate matter (e.g., PM₁₀, PM_{2.5} particles less than 10 micrometers diameter and less than 2.5 micrometers diameter) and ozone (O₃), while polyaromatic hydrocarbons (PAHs) have been recently

identified as pollutants of concern (EEA, 2013). Air quality is certainly of concern in Rio de Janeiro and this focuses on the presence of particulate matter (PM₁₀; PM_{2.5}). In a recent review of the evidence on the health impacts of air pollution the World Health Organisation (WHO) state that the previous causal link between PM_{2.5} and adverse health impact in earlier guidelines has been strengthened by recent evidence (WHO, 2013). Short and long term exposure to PM_{2.5} were noted to result in adverse health impacts, even where exposure was below the current recommended WHO annual limit of 10µg/m³. Such findings highlight the need for continued measures to reduce air pollution. In addition, this review of recent evidence also highlights the links between exposure to NO₂ and mortality/morbidity and exposure is noted to be particularly elevated near roads as a result of traffic emissions (WHO, 2013).

Rio does not escape the effects of degraded air quality. For instance, Sousa *et al.* (2012a) measured air quality at two separate sites in Rio de Janeiro on an hourly basis between 2000 and 2005. PM₁₀ values at these sites were found to exceed EU annual mean limit value (40µg/m³) every year, on some occasions being over double the limit value. The authors attributed these high levels of observed PM₁₀ primarily to traffic emissions. In the second part of their study Sousa *et al.* (2012b) showed that ambient air pollution levels in the city during the measured period were linked to hospital admission rates in children and elderly populations for respiratory issues.

The above findings are supported by Gioda *et al.* (2016) who analyzed data from 1968 to 2013 (Gioda *et al.* 2016). They reported that total suspended particulates levels exceeded the annual mean Brazilian limit value of 80µg/m³ on every occasion and PM₁₀ levels were also found to be in breach of the annual mean Brazilian limit value of 50µg/m³ and significantly above the WHO guidelines levels. While some reduction in PM₁₀ was noted in certain areas, increases were also observed in other venues. For instance, PM₁₀ levels at the Cidade de Deus station on the West side of Rio where the Olympic park is situated were found to average over 90µg/m³ in the time period from 1998 to 2013.

Environmental Concerns at Previous Olympic Venues

The focus on evaluating, managing and controlling environmental hazards for athletes is not a new issue. In 1968, the high altitude (>2,250m) of the XIX Olympiad in Mexico gave rise to investigations on the effect of lowered atmospheric pressure on running performance (Jokl *et al.*, 1969). Four decades later at the 2008 Beijing Olympics this deleterious view of the natural environment still pervaded. The 2008 games were dominated by controversies over air pollution as Beijing then ranked second among the World's most polluted cities according to Lippi *et al.* (2008).

While there remains little doubt as to the dangers associated with even low levels of pollutants, the question of how these risks translate down to the individual elite performer and whether performance would be compromised has not been definitively answered. Lippi *et al.* (2008) addressed these issues and commented: "although the athletes who will be competing in Beijing are physiologically very different to the participants in most published studies, and it is therefore difficult to predict individual responses, there is little doubt that the presence of several air pollutants might be detrimental to athletic performance" (p. 698). Similarly, McKenzie and Boulet (2008) noted that the performance of all athletes could be inhibited both psychologically and physiologically by poor air quality and moreover, that "the risk of respiratory problems is greatest for athletes participating in outdoor endurance events at sites with poor air quality" (2008; p. 543).

In 2004 the Beijing Olympic organizing committee BOCOG had set the following targets for the Olympic Games period: (1) that concentrations of SO₂, NO₂, and O₃ should meet WHO guidelines; and (2) that particle concentrations should be comparable to levels in major cities in the developed countries. Attempts to model both PM_{2.5} and Ozone levels in Beijing using the Community Multiscale Air Quality (CMAQ) developed by the US Environmental Protection Agency (Byun and Ching, 1999) were undertaken. These conveyed that the regional transport of emissions from the neighbouring provinces was likely to undermine local attempts at mitigating pollution (Streets et al., 2008). These measures included an “odd-even ban” which meant that private vehicles could only be used on odd or even days depending on the last digit of their license plate (Schleicher et al., 2012). However, post-Olympic Games studies have provided support for the mitigation measures used to reduce particulate air pollution during the games period. Schleicher et al. (2012) reported that particulate air pollution in Beijing decreased significantly during the Summer Olympic Games between the 8th and 24th of August when mitigation measures were strictly enforced. What is surprising however, is that the potential positive impact of the natural environment has been largely overlooked in the context of elite athletic performance.

Benefits of Exposure to the Green and Blue Environments

It is 15 years since researchers advocated that “we need to act on emerging evidence of environmental health benefits” (Frumkin, 2001, p.239). Since the term biophilia hypothesis was coined in 1984, tentative evidence has emerged for the positive effects from human-environment interactions. Wilson (1984) proposed that we have an evolutionary preference for interactions with the natural world. Subsequent research has led to the emergence of new concepts including green exercise term and blue mind, a term that has been used to label the potential positive influence of the aquatic environment on wellbeing, attention and our health (Nichols, 2014). We emphasize that blue-green is not only healthier, in the biological sense, we propose that it increases well-being and all forms of health and performance, and this is a hypothesis that is testable.

One challenge with these concepts is that the natural environment includes many different types of green space and blue spaces such as (e.g., urban parks) and a typology may be required to more accurately distinguish built versus organic environments. Individual preferences or nature relatedness may be the mediator of the positive effects of exposure to natural environments (Nisbet et al., 2009). Nevertheless, tentative evidence has emerged according to a recent systematic review. Thompson-Coon et al. (2011) reported, compared with exercising indoors, exercising in natural environments was linked with greater feelings of revitalization, positive engagement and enhanced mood. If supported consistently, it is plausible that these effects may have implications for well-being, mental health, exercise adherence and peak performance. Large scale studies using survey data and data on greenness from satellite images have indicated that green spaces are linked to better general and mental health (Triguero-Mas et al., 2015). Based on their analysis, they concluded that mechanisms other than physical activity and social support may explain the associations. A further explanation, the attention restoration theory, was investigated by Berman et al. (2012) who demonstrated that walking in nature had both cognitive and affective benefits for depressed patients relative to walking in urban environments. It is clear that robust evidence for the mechanisms underlying the aforementioned benefits of contact with nature are not yet established (Kuo, 2015).

Are we going in the right direction?

The 2020 Olympic games will take place in Tokyo, a megacity which Gurjar et al. (2008) gave a megacity air-pollution index (MPI) of -0.3 in their study based on total air pollution levels in megacities (negative MPI values tend towards a good air quality classification, whilst positive values tend towards poor air quality). For comparison the only megacity considered in the study that had an improved MPI was Osaka-Kobe with a ranking of 0.4. A follow on study (Gurjar *et al.* 2010) showed that the excess number of deaths in megacities was closely linked to total suspended particulates levels. Megacities include Osaka Kobe, Tokyo, and New York had a low number of excess mortality cases (60-500). Beijing in contrast, has an excess mortality rate of 11,500/yr. Rio ranks in between with an estimated excess mortality rate of 2,000/yr. London also has its own air quality issues which have been very topical in recent times as EU limit values are frequently breached in a number of regions. A study by Stedman (2004) highlighted the importance of considering air quality levels and climate as a whole and estimated that during a heat-wave in the UK when temperatures peaked at 38.5°C there were between 423 and 769 excess deaths in England and Wales due to elevated levels of ozone and PM₁₀. One would question therefore, in what environment an elite athlete would prefer to perform and whether they can be sure that they are not putting themselves at a higher risk than the rest of the population by exerting themselves to their maximum ability in their drive for sporting success?

Tokyo has the highest population of any city in the world at almost 43 million inhabitants and has a population density of 4,400 people per km². While this population density is much lower than Mumbai (32,400/km), it remains significantly higher than US cities such as New York (1,800/km²) which have comparable MPI ratings. Sustaining such population density levels and retaining some degree of greenness is a challenge faced by many cities. Can a general alienation from nature be avoided and is it possible to retain the benefits of exercise in blue and green natural spaces for both the general population and elite athlete alike?

Forest bathing has become increasingly popular in Japan in recent years and preliminary evidence supporting its beneficial effects has emerged. Li (2010) suggested that a forest bathing trip (participants from Tokyo experienced a two night trip to a forest) showed that these individuals maintained a better immune response than controls. The effects of exercise coupled with the forest environment has also been shown to have a positive effect on cardiovascular and metabolic parameters, lowering blood pressure (Li *et al.* 2011).

Perhaps this is the type of model that we need to follow and research should focus on quantifying the time needed in these green spaces to maintain a healthy state of mind. Implicit in this research would be a consideration of the urban density and pre-existing green spaces accessible to the population at large. The environmental quality of these green spaces must also be proportional to their positive health effects, and it must always be remembered that just because an area is green does not automatically imply environmental cleanliness. Future studies must take both factors into account when measuring physiological and psychological effects. Our preliminary hypothesis is that a green space with an environmental quality of superior quality to an otherwise comparable green space could result in better physical and psychological health and potentially better athletic performance.

For athletes spending time in the Olympic environment, questions must be asked regarding psychological well-being and whether exposure to green spaces facilitates athletes achieving achieve peak performances. And indeed, is there a minimum environmental quality that must be present before positive benefits of the environment are observed? De Wolfe et

al. (2011) investigated athletic performance across four locations and found a significant correlation between greenness and performance ($R^2=0.61$).

We're all in this together

Bickerstaff and Walker (2001) concluded that community involvement approaches which draw upon local people in identifying the environmental issues that affect them and how they can be involved in designing and implementing policy and communication responses to the problems will lead to a greater sensitivity to local diversity. Encouraging society at large to become more active and also less polluting can, in the long term, lead to a cleaner, greener and happier society. De Hartog et al. (2010) concluded that the health benefits of a modal shift from driving to cycling were substantially larger than the risks and that aside from quantifiable and measureable effects, societal benefits are even larger. There is clearly a need for evidence-based research to promote the psychological health effects of a greener society and the provision and use of green and blue spaces for physical activity. It has been four decades since Craik, in a review of environmental psychology, commented that "a broad thin, but rapidly expanding layer of empirical research underlies current knowledge in environmental psychology (1973, p. 429). New research with a transdisciplinary perspective is urgently required.

Avenues for Future Research

Future research needs to include relevant environmental monitoring to quantify the greenness of the competition landscape from an environmental health perspective. There exists great disparity in the natural influences which pervade various sports. Pool swimming for example may be considered to take place in an entirely artificial environment with little potential for green influences. In contrast marathon swimmers are subjected to the natural environment albeit of varying quality. Research needs to assess if and how, the quality of these environments can affect athlete health, well-being and ultimately performance. Furthermore, by using samples of elite athletes it will be possible to assess attitudes towards the environment and subsequently devise the most appropriate and effective means of bringing green and blue spaces into sport. Such research will differentiate between sports that are ordinarily held in green/blue spaces and those which take place in highly artificial or hybrid artificial/natural environments.

We emphasise the importance at each step of considering environmental quality in pursuing these future research avenues. We suggest that the positive mental health benefits to athletes that can be gained from blue and green spaces relates not only to the visual appearance of these spaces but also the environmental characteristics that we may not be able to see such as air quality, water quality and biodiversity.

Conclusions

Athletes competing at the Tokyo 2020 Olympics can potentially benefit from a more comprehensive understanding of the impact of activity in green and blue natural spaces on health and well-being. Green and blue may well be the new pathway to achievement not just on the individual level for mental health, nor simply on a societal level by increasing pro-environmental behaviour but also by the continued greening of the Olympic movement in successive Olympiad. Perhaps the IOC should provide more weight to the environmental ethos of hosting cities when making their selections and indeed by doing so present athlete health and wellbeing as a key priority in the path to success. We propose a re-framing of the environment in the Olympic context, a perspective that goes beyond toxicity, and instead

accounts for the positive effect of the environment on health, well-being and athletic performance.

References:

- Arnold, R., and Sarkar, M. (2015). Preparing athletes and teams for the Olympic Games: Experiences and lessons learned from the world's best sport psychologists. *Int. J. Sport. Exer. Psychol.* 13 (1), 4-20. doi: 10.1080/1612197X.2014.932827
- Berman, M. G., Kross, E., Krpan, K. M., Askren, M. K., Burson, A., Deldin, P. J., ... Jonides, J. (2012). Interacting with nature improves cognition and affect for individuals with depression. *J. Affec. Disord.* 140(3), 300–305. <http://doi.org/10.1016/j.jad.2012.03.012>
- Bickerstaff, K., and Walker, G. (2001). Public understandings of air pollution: the 'localisation' of environmental risk. *Glob. Environ. Chang.* 11(2), 133-145.
- Byun, D.W., Ching, J.K.S. (1999). Science algorithms of the EPA Models-3 Community Multiscale Air Quality (CMAQ) Modeling System. EPA Report No. EPA-600/R-99/030.
- Craik, K. H. (1973). Environmental psychology. *Ann Rev Psychol.* 24: 403-422. DOI: 10.1146/annurev.ps.24.020173.002155
- De Hartog, J. J., Boogaard, H., Nijland, H. and Hoek, G. (2010). Do the health benefits of cycling outweigh the risks? *Environ. Heal. Persp.* 1109-1116. doi: 10.1289/ehp.0901747.
- De Wolfe, J. Waliczek, T. M., and Zajicek, J. M. (2011) The relationship between levels of greenery and landscaping at track and field sites, anxiety, and sports performance of collegiate track and field athletes. *HortTechnology* 21 (3), 329-325.
- E. E. A. (2013) *Status of black carbon monitoring in ambient air in Europe*. EEA Technical report, 18.
- European Commission (2013). Communication from the Commission to the European Parliament, the Council, The European Economic And Social Committee and the Committee of The Regions, Brussels.
- Fistarol, G. O., Coutinho, F. H., Moreira, A. P. B., Venas T., Cánovas A., de Paula S. E. M. Jr., Coutinho R. et al. (2015). Environmental and sanitary conditions of Guanabara Bay, Rio de Janeiro. *Front. Microbiol.* 6:1232. doi: 10.3389/fmicb.2015.01232
- Fletcher, D., and Sarkar, M. (2012). A grounded theory of psychological resilience in Olympic champions. *Psychol. Sport. Exerc.* 13, 669–678. Doi: 10.1016/j.psychsport.2012.04.007
- Fletcher, D., Hanton, S., Mellalieu, S. D., and Neil, R. (2012). A conceptual framework of organizational stressors in sport performers. *Scand. J. Med. Sci. Sports* 22, 545–557. doi: 10.1111/j.1600-0838.2010.01242.x
- Frumkin, H. (2001). Beyond toxicity: Human health and the natural environment. *Am. J. Prev. Med.* 20 (3), 234-240.
- Gioda, A., Ventura, L. M. B., Ramos, M. B., and Silva, M. P. R. (2016). Half century monitoring air pollution in a Megacity: A case study of Rio de Janeiro. *Water Air Soil Poll* 227(3), 1-17. doi:10. 1007/ s11270-016-2780-8
- Greenleaf, C., Gould, D., and Diefenbach, K. (2001). Factors influencing Olympic performance: Interviews with Atlanta and Nagano U. S. Olympians. *J. Appl. Sport Psychol.* 13, 154-184. Doi: 10.1080/104132001753149874
- Gurjar, B., Butler, T., Lawrence, M. and Lelieveld, J. (2008). Evaluation of emissions and air quality in megacities. *Atmos. Environ.* 42(7), 1593-1606.

- doi:10.1016/j.atmosenv.2007.10.048
- Gurjar, B., Jain, A., Sharma, A., Agarwal, A., Gupta, P., Nagpure, A. and Lelieveld, J. (2010) Human health risks in megacities due to air pollution. *Atmos. Environ.* 44(36), 4606-4613. doi:10.1016/j.atmosenv.2010.08.011
- Guy, J. J., Deakin, G. B., Edwards, A. M. Miller, A. M., and Pyne, D. B. (2015). Adaptation to hot environmental conditions: an exploration of the performance basis, procedures and future directions to optimise opportunities for elite athletes. *Sports Med.* 45 (3): 303-311. doi: 10.1007/s40279-014-0277-4.
- Hodge, K. (2010). Working at the Olympics. In *Routledge Handbook of Applied Sport psychology: A Comprehensive Guide for Students and Practitioners*, eds. S. J. Hanrahan & M. Andersen (London: Routledge) 405-413.
- Jokl, E., Jokl, P., and Seaton, D. C. (1969). Effect of altitude upon 1968 Olympic Games running performances. *Int. J. Biometeorol.* 13 (3), 309-311.
- Kuo, M. (2015). How might contact with nature promote human health? Promising mechanisms and a possible central pathway. *Front. Psychol.* 6. doi:10.3389/fpsyg.2015.01093
- Li, Q. (2010). Effect of forest bathing trips on human immune function. *Environ. Health Prev. Med.* 15(1), 9-17. doi: 10.1007/s12199-008-0068-3
- Li, Q., Otsuka, T., Kobayashi, M., Wakayama, Y., Inagaki, H., Katsumata, M., Hirata, Y., Li, Y., Hirata, K., and Shimizu, T. (2011). Acute effects of walking in forest environments on cardiovascular and metabolic parameters. *Eur. J. Appl. Physiol.* 111(11), 2845-2853. doi: 10.1007/s00421-011-1918-z
- Lippi, G., Guidi, G. C., & Maffulli, N. (2008). Air pollution and sports performance in Beijing. *Int. J. Sports Med.* 29(8), 696-698. doi:10.1055/s-2008-1038684
- McKenzie, D. C., and Boulet, L-P. (2008). Asthma, outdoor air quality and the Olympic Games *CMAJ* 179 (6). doi: 10.1503/cmaj.080982
- Nichols, W. J. (2014). *Blue Mind*. NY: Little Brown & Co.
- Nisbet, E. K., Zelenski, J. M., & Murphy, S. A. (2009). The Nature Relatedness Scale: Linking individuals' connection with nature to environmental concern and behavior. *Environ. Behav.* 41, 715-740.
- Schinke, R. J., Battocchio, R. C., Dube, T. V., Lidor, R., Tenenbaum, G., and Lane, A. M. (2012). Adaptation processes affecting performance in elite sport. *J. Clin. Sport Psychol.* 6, 180-195.
- Schleicher, N., Norra, S., Chen, Y., Chai, F. and Wang, S. (2012). Efficiency of mitigation measures to reduce particulate air pollution-A case study during the Olympic Summer Games 2008 in Beijing, China. *Sci. Total. Environ.* 427-428, 146-158. doi:10.1016/j.scitotenv.2012.04.004
- Sousa, S., Pires, J., Martins, E., Fortes, J., Alvim-Ferraz, M., and Martins, F. (2012a). Short-term effects of air pollution on respiratory morbidity at Rio de Janeiro—Part I: Air pollution assessment. *Environ. Int.* 44, 18-25. doi: 10.1016/j.envint.2012.01.005.
- Sousa, S., Pires, J., Martins, E., Fortes, J., Alvim-Ferraz, M., and Martins, F. (2012b). Short-term effects of air pollution on respiratory morbidity at Rio de Janeiro—Part II: Health assessment. *Environ. Int.* 43, 1-5. doi: 10.1016/j.envint.2012.02.004.
- Stedman, J. R. (2004). The predicted number of air pollution related deaths in the UK during the August 2003 heatwave. *Atmos. Environ.* 38(8), 1087-1090.
- Streets, D. G., Fu, J. S., Jang, C. J., Hao, J., He, K., Tang, X., ... & Wang, L. (2007). Air quality during the 2008 Beijing Olympic games. *Atmos. Environ.* 41(3), 480-492. doi:10.1016/j.atmosenv.2006.08.046
- Thompson Coon, J., Boddy, K., Stein, K., Whear, R., Barton, J., & Depledge, M. H. (2011). Does participating in physical activity in outdoor natural environments have a greater

- 363 effect on physical and mental wellbeing than physical activity indoors? A systematic
364 review. *Environ. Sci. Technol.* 45(5), 1761-1772. doi:10.1021/es102947t
365 Triguero-Mas, M., Dadvand, P., Cirach, M., Martínez, D., Medina, A., Mompert, A., ... &
366 Nieuwenhuijsen, M. J. (2015). Natural outdoor environments and mental and physical
367 health: relationships and mechanisms. *Environ. Int.* 77, 35-41.
368 doi:10.1016/j.envint.2015.01.012
369 WHO (2013). *Review of evidence on health aspects of air pollution – REVIHAAP project:*
370 *final technical report*. WHO/Europe.
371 Wilson, E. O. (1984). *Biophilia*. Cambridge, MA: Harvard University Press.

In review